APPLICATION FOR
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in the name of

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for

ALL-IN-ONE WIRELESS NETWORK DEVICE

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BACKGROUND

[0001]   The present invention relates generally to wireless data communications. More particularly, the present invention relates to all-in-one wireless network devices.

[0002]   Many wireless network devices are available to facilitate data communications and network access at home and in the workplace, including wireless access points, wireless clients, wireless bridges, wireless repeaters, and even wireless-enabled laptop computers and personal digital assistants. FIG. 1 shows a conventional combination wireless network device 100. Wireless network device 100 comprises a processor 102, a wireless port 104, a memory controller 110, a non-volatile memory 112, a volatile memory 114, and an antenna 116.

[0003]   FIG. 2 shows a conventional architecture 200 for a conventional combination wireless network device 100 that can act as either a wireless access point or a wireless client. Architecture 200 comprises a plurality of software images comprising a software image 202A for the wireless access point and a software image 202B for the wireless client, and wireless port 104 of FIG. 1. Image 202A comprises a conventional operating system 204A, a wireless access point application 206A, and a media access controller (MAC) device driver 210A. Image 202B comprises a conventional operating system 204B, a wireless client application 206B, and a MAC device driver 210B. Wireless port 104 comprises a MAC 212 and a wireless physical-layer device (PHY) 214.

[0004]   Conventional architecture 200 is limited in that only one wireless application can execute at a time. That is, according to architecture 200, combination wireless network device 100 can act either as a wireless access point or as a wireless client, but cannot act as both concurrently.

[0005]   Furthermore, switching between modes is slow. For example, in order to switch from wireless access point mode to wireless client mode, processor 102 must

reboot and load wireless client image 202B into volatile memory 114 before entering wireless client mode.

[0006]   Finally, architecture 200 is inefficient because operating system 204 is replicated in each image 202, and can account for up to 2/3 of the storage space required by each image 202. This inefficiency increases the storage requirements for both non-volatile memory 112 and volatile memory 114, as well as the time required to transfer each image 202 from non-volatile memory 112 to volatile memory 114. These storage requirements mandate a larger, less portable, and more expensive package for conventional combination wireless network device 100.

SUMMARY

[0007]   In general, in one aspect, the invention features a method, apparatus, and computer-readable media for a wireless network device for communicating with a network comprising. The apparatus comprises a memory to store an image comprising a plurality of virtual machines and only one multi-tasking operating system, wherein each of the virtual machines comprises a wireless network application to execute on the multi-tasking operating system; a processor to execute the virtual machines; and a port comprising a physical-layer device to communicate with the network, and a media access controller to communicate with the physical-layer device and the processor.

[0008]   Particular implementations can include one or more of the following features. A wireless network device is compliant with a standard selected from the group consisting of IEEE standards 802.11, 802.11a, 802.11b, 802.11g and 802.11n. The memory comprises a non-volatile memory, and the apparatus further comprises a volatile memory; and a memory controller to create a copy of the image from the non-volatile memory to the volatile memory; wherein the processor executes the virtual machines from the volatile memory. The memory comprises a virtual machine queue for each virtual machine and a processor queue for the processor; the processor stores data to be processed for the virtual machine being executed by the processor in the processor queue; each virtual machine creates a copy in the respective virtual machine queue of the data in the processor queue when the processor is executing the respective virtual machine; and when the processor resumes executing one of the virtual machines after executing another of the virtual machines, the one of the virtual machines copies the data from the respective virtual machine queue to the processor queue. The wireless network applications are selected from the group consisting of a

wireless network access point; a wireless network client; a wireless network point-to-point bridge; a wireless network multi-point bridge; and a wireless network repeater. The image further comprises a plurality of virtual machine device drivers to communicate with the virtual machines; and a media access controller device driver to communicate with the virtual machine device drivers and the media access controller. The apparatus further comprises an input device to select one or more of the virtual machines; wherein the processor executes the virtual machines selected by the input device. The processor executes a plurality of the virtual machines concurrently. The virtual machines comprise a wireless network access point virtual machine and a wireless network client virtual machine; wherein the processor executes the wireless network access point virtual machine and the wireless network client virtual machine concurrently; wherein the wireless network client virtual machine comprises a first virtual wireless port to communicate with the port, and a first virtual bridge to communicate with the first virtual wireless port; and wherein the wireless network access point virtual machine comprises a second virtual wireless port to communicate with the port, a virtual distribution service port to communicate with the first virtual bridge, and a second virtual bridge to communicate with the second virtual wireless port and the virtual distribution service port.

[0009]   In general, in one aspect, the invention features a method, apparatus, and computer-readable media for a wireless network device for communicating with a network. The apparatus comprises a memory to store an image comprising a plurality of virtual machines and only one multi-tasking operating system, wherein each of the virtual machines comprises a wireless network application to execute on the multi-tasking operating system; a processor to execute the virtual machines; and a bus to communicate with the processor and the network. The wireless network device is compliant with a standard selected from the group consisting of IEEE standards 802.11, 802.11a, 802.11b, 802.11g and 802.11n. The memory comprises a non-volatile memory, and the apparatus further comprises a volatile memory; and a memory controller to create a copy of the image from the non-volatile memory to the volatile memory; wherein the processor executes the virtual machines from the volatile memory. The memory comprises a virtual machine queue for each virtual machine and a processor queue for the processor; wherein the processor stores data to be processed for the virtual machine being executed by the processor in the processor queue; wherein each virtual machine creates a copy in the respective virtual machine queue of the data in the processor queue when the processor is executing the

respective virtual machine; and wherein when the processor resumes executing one of the virtual machines after executing another of the virtual machines, the one of the virtual machines copies the data from the respective virtual machine queue to the processor queue. The image further comprises a plurality of virtual machine device drivers to communicate with the virtual machines; and a bus interface driver to communicate with the virtual machine device drivers and the bus. The apparatus further comprises a physical-layer device to communicate with the network; and a media access controller to communicate with the physical-layer device and the bus. The image further comprises a plurality of virtual machine device drivers to communicate with the virtual machines; a first bus interface driver to communicate with the virtual machine device drivers and the bus; a second bus interface driver to communicate with the bus; and a media access controller device driver to communicate with the second bus interface driver and the media access controller. The wireless network applications are selected from the group consisting of a wireless network access point; a wireless network client; a wireless network point-to-point bridge; a wireless network multi-point bridge; and a wireless network repeater. The apparatus further comprises an input device to select one or more of the virtual machines; wherein the processor executes the virtual machines selected by the input device. The processor executes a plurality of the virtual machines concurrently. The virtual machines comprise a wireless network access point virtual machine and a wireless network client virtual machine; wherein the processor executes the wireless network access point virtual machine and the wireless network client virtual machine concurrently; wherein the wireless network client virtual machine comprises a first virtual wireless port to communicate with the port, and a first virtual bridge to communicate with the first virtual wireless port; and wherein the wireless network access point virtual machine comprises a second virtual wireless port to communicate with the port, a virtual distribution service port to communicate with the first virtual bridge, and a second virtual bridge to communicate with the second virtual wireless port and the virtual distribution service port.

[0010]   The details of one or more implementations are set forth in the accompanying drawings and the description below. Other features will be apparent from the description and drawings, and from the claims.

DESCRIPTION OF DRAWINGS

[0011]   FIG. 1 shows a conventional combination wireless network device.

[0012]   FIG. 2 shows a conventional architecture for a conventional combination wireless network device that can act as either a wireless access point or a wireless client.

[0013]   FIG. 3 shows an all-in-one wireless network device according to a preferred embodiment.

[0014]   FIG. 4 shows an architecture for the all-in-one wireless network device of FIG. 3 according to a preferred embodiment employing an embedded processor.

[0015]   FIG. 5 shows a process for the all-in-one wireless network device of FIG. 3 and the architecture of FIG. 4 according to a preferred embodiment.

[0016]   FIG. 6 shows an architecture for the all-in-one wireless network device of FIG. 3 according to a preferred embodiment employing a host processor such as the central processing unit (CPU) of a laptop computer.

[0017]   FIG. 7 shows an architecture enhancement that prevents any data loss.

[0018]   FIG. 8 shows a wireless network comprising a universal repeater according to a preferred embodiment of the present invention.

[0019]   FIG. 9 shows an architecture for the universal repeater of FIG. 8 according to a preferred embodiment employing an embedded processor.

[0020]   The leading digit(s) of each reference numeral used in this specification indicates the number of the drawing in which the reference numeral first appears.

DETAILED DESCRIPTION

[0021]   Embodiments of the present invention comprise various all-in-one wireless network devices. FIG. 3 shows an all-in-one wireless network device 300 according to a preferred embodiment. All-in-one wireless network device 300 comprises a processor 302, a wireless port 304, an optional wired port 306, an optional input device 308, a memory controller 310, a non-volatile memory 312, a volatile memory 314, and an antenna 316. Optional wired port 306 can be used to connect all-in-one wireless network device 300 to wired networks such as Ethernet networks available at work, at home, at hotels, and so on. Such embodiments are compliant, for example, with IEEE standards 802.11, 802.11a, 802.11b, 802.11g and 802.11n.

[0022]   FIG. 4 shows an architecture 400 for all-in-one wireless network device 300 according to a preferred embodiment employing an embedded processor. Architecture

400 comprises a software image 402 and wireless port 304 of FIG. 3. Image 402 comprises a multi-tasking operating system 404, a plurality of virtual machines 406A through 406N each having one of a plurality of virtual machine (VM) device drivers 408A through 408N, and a media access controller (MAC) device driver 410. Wireless port 304 comprises a MAC 412 and a wireless physical-layer device (PHY) 414.

[0023]   A virtual machine is a software architectural block that allows multiple applications to share one hardware element, such as a wireless port. Each virtual machine 406 comprises a wireless network application to execute on multi-tasking operating system 404. The wireless network applications can include wireless network access points, wireless network clients, wireless network point-to-point bridges, wireless network multi-point bridges, wireless network repeaters, and the like. Multi-tasking operating system 404 can be implemented as any multi-tasking operating system such as eCos, which is described at http://sources.redhat.com/ecos/about.html, the contents of which are incorporated herein by reference.

[0024]   FIG. 5 shows a process 500 for all-in-one wireless network device 300 and architecture 400 according to a preferred embodiment. Image 202 is stored in non-volatile memory 312. When all-in-one wireless network device 300 powers up (step 502), memory controller 310 creates a copy of image 202 in volatile memory 314 (step 504). Processor 302 executes virtual machines 406 from volatile memory 314 (step 506).

[0025]   In some embodiments, two or more predetermined virtual machines execute concurrently whenever all-in-one wireless network device 300 powers up, so no user selection of modes is required. For example, in a universal repeater embodiment, described in detail below, an access point virtual machine and a client virtual machine execute concurrently. However, in other embodiments, a user can manipulate input device 308 to select one or more modes of operation, and processor 302 executes the corresponding virtual machines 406 according to the user's mode selection. Input device 308 can be a simple slide switch, a touch screen, or other graphical user interface.

[0026]   FIG. 6 shows an architecture 600 for all-in-one wireless network device 300 according to a preferred embodiment employing a host processor such as the central processing unit (CPU) of a laptop computer. Architecture 600 comprises a software

image 602 and a wireless port 304 such as wireless port 304 of FIG. 3. Image 602 comprises a multi-tasking operating system 604, a plurality of virtual machines 606A through 606N each having one of a plurality of virtual machine (VM) device drivers 608A through 608N, and a MAC device driver. Wireless port 304 comprises MAC 412 and wireless PHY 414.

[0027]   Architecture 600 further comprises a host bus 616 that is used for communication between wireless port 304 and virtual machines 606. A host interface bus driver 618 allows communications between virtual machine device drivers 608 and host bus 616. A host interface bus driver 618 allows communications between virtual machine device drivers 608 and host bus 616. A port interface bus driver 620 allows communications between wireless port 304 and host bus 616. Architecture 600 operates in a manner similar to that described for architecture 400 as process 500 of FIG. 5.

[0028]   In architectures 400 and 600 the virtual machines execute concurrently by each using the processor in turn. However, the potential exists for data such as network packets to be lost when the processor turns from one virtual machine to another. FIG. 7 shows an architecture enhancement 700 that prevents any such data loss. In architecture 700, the processor has a processor queue 702, and each virtual machine 706A through 706N has a respective virtual machine queue 704A through 704N.

[0029]   The processor stores data to be processed for the virtual machine 706 being executed by the processor in the processor queue 702 according to well-known methods. But according to embodiments of the present invention, each virtual machine 706 maintains a copy in its virtual machine queue 704 of the data in the processor queue 702 when the processor is executing that virtual machine 706. For example, when the processor is executing virtual machine 706A, virtual machine 706A maintains a copy in its virtual machine queue 704A of the data in the processor queue 702.

[0030]   When the processor is executing another virtual machine 706, the copy is kept intact. Returning to the example, when the processor is executing virtual machine 706N, virtual machine 706A keeps in virtual machine queue 704A an intact copy of the processor queue 702 as of the time when the processor stopped executing virtual machine 706A.

[0031]   When the processor resumes executing a virtual machine 706 after executing another virtual machine 706, the resuming virtual machine 706 copies the data from the virtual machine queue 704 of the resuming virtual machine 706 to the processor queue 702. Returning to the example, when the processor resumes executing virtual machine 706A after executing virtual machine 706N, virtual machine 706A copies the data from virtual machine queue 704A to the processor queue 702. The processor them resumes execution of virtual machine 706A using the data in processor queue 702. In this way, the processor does not lose data when switching between virtual machines.

[0032]   Embodiments of the present invention include a universal wireless repeater to extend the range of wireless connections. Conventional wireless repeaters employ proprietary wireless protocols, forcing a user to purchase all of his wireless equipment from the same manufacturer. The universal repeaters of the present invention employ only standard wireless protocols, freeing the user to purchase whatever wireless equipment he desires.

[0033]   FIG. 8 shows a wireless network 800 comprising a wireless universal repeater 802 according to a preferred embodiment of the present invention. Wireless network 800 also comprises a conventional wireless access point 804 that communicates with wireless universal repeater 802 and a conventional wired network 806 such as the Internet. Wireless network 800 further comprises a conventional wireless client 810 that communicates with wireless universal repeater 802 and a conventional host 808 such as a personal computer.

[0034]   Wireless access point 804 comprises a wired wide-area network port 824 to communicate with wired network 806, for example over a cable, a wireless local-area network (WLAN) port 828, and a wireless access point application 826 to exchange data traffic between ports 824 and 828, as is well-known in the relevant arts.

[0035]   Wireless client 810 comprises a WLAN port 830 and a wireless client application 832 to exchange data traffic between port 830 and host 808, as is also well-known in the relevant arts. However, due to factors such as distance and blockage, wireless client 810 is unable to communicate directly with wireless access point 804.

[0036]   Wireless universal repeater 802 provides the connectivity between wireless client 810 and wireless access point 804. Wireless universal repeater 802 comprises a wireless WLAN port 816 to communicate with wireless access point 804 over

wireless link 812 and a WLAN port 822 to communicate with wireless client 810 over wireless link 814. Wireless links 812 and 814 can use the same band or different bands. Wireless universal repeater 802 executes two virtual machines concurrently, according to the techniques described above: wireless client virtual machine 818 and wireless access point virtual machine 820. Wireless virtual machines 818 and 820 together exchange data between wireless ports 816 and 822, thereby providing connectivity for wireless network 800 using standard wireless protocols such as IEEE 802.11 for wireless links 812 and 814.

[0037]   In some embodiments of wireless universal repeater 802, wireless access point virtual machine 820 and wireless client virtual machine 818 share a single hardware WLAN port that communicates with both wireless access point 804 and wireless client 810. FIG. 9 shows an architecture 900 for an embodiment employing an embedded processor. A similar architecture employing a host processor will be apparent to one skilled in the relevant arts after reading this description. Such embodiments represent a significant cost reduction over repeaters using two hardware ports.

[0038]   Architecture 900 comprises a software image 902 and wireless port 304 of FIG. 3. Image 902 comprises a multi-tasking operating system 904, a client virtual machine 906A having a virtual machine (VM) device driver 908A, an access point virtual machine 906B having a VM device driver 908B, and a media access controller (MAC) device driver 910. Wireless port 304 comprises a MAC 412 and a wireless physical-layer device (PHY) 414.

[0039]   Client virtual machine 906A comprises a virtual bridge 916A and a virtual wireless port 912A. Access point virtual machine 906B comprises a virtual bridge 916B, a virtual wireless port 912B, and a virtual distribution service (DS) port 914. Virtual bridges and virtual ports are software realizations of their hardware equivalents, as is well-known in the relevant arts.

[0040]   Virtual wireless port 912A exchanges data between client virtual machine 906A and access point 804 of FIG. 8 using wireless port 304. Similarly, virtual wireless port 912B exchanges data between access point virtual machine 906B and client 810 of FIG. 8, also using wireless port 304. Virtual DS port 914 exchanges data between client virtual machine 906A and access point virtual machine 906B.

[0041]   Bridge module 916B of access point virtual machine 906B maintains a bridge table or the like to distinguish local WLAN traffic (that is, traffic between client 810

and other such clients) from external traffic (that is, traffic between client 810 and network 804). In some embodiments, bridge module 916B employs a learning process to populate a bridge table for this purpose. Virtual bridge 910B directs traffic directed to the local WLAN to virtual wireless port 912B so it can reach the proper destination client in the local WLAN, and directs traffic not directed to the local WLAN to virtual DS port 914 so it can reach the proper destination in network 806 through access point 804.

[0042]   Embodiments of the present invention are able to execute multiple wireless applications concurrently, for example in the universal repeater embodiment described above. Furthermore, switching between modes is fast and transparent to the user. In contrast to conventional combination wireless network devices, no rebooting is necessary. Finally, because the architectures of the preferred embodiments are efficient, all-in-one network devices according to preferred embodiments of the present invention can be light, inexpensive, and small enough to fit in a shirt pocket.

[0043]   Embodiments of the present invention are ideal for new wireless users. New purchasers of wireless-enabled laptop computers often return home, power up their new laptops, and are disappointed to learn that no wireless connectivity awaits them. An embodiment of the invention featuring a wireless access point could be bundled with wireless laptops for sale. On returning home with the new laptop, a user could simply plug the all-in-one wireless network device into a phone jack or the like, power up the laptop, and enjoy instant wireless networking.

[0044]   The invention can be implemented in digital electronic circuitry, or in computer hardware, firmware, software, or in combinations of them. Apparatus of the invention can be implemented in a computer program product tangibly embodied in a machine-readable storage device for execution by a programmable processor; and method steps of the invention can be performed by a programmable processor executing a program of instructions to perform functions of the invention by operating on input data and generating output. The invention can be implemented advantageously in one or more computer programs that are executable on a programmable system including at least one programmable processor coupled to receive data and instructions from, and to transmit data and instructions to, a data storage system, at least one input device, and at least one output device. Each computer program can be implemented in a high-level procedural or object-oriented programming language, or in assembly or machine language if desired; and in any case, the language can be a compiled or interpreted language. Suitable processors

include, by way of example, both general and special purpose microprocessors. Generally, a processor will receive instructions and data from a read-only memory and/or a random access memory. Generally, a computer will include one or more mass storage devices for storing data files; such devices include magnetic disks, such as internal hard disks and removable disks; magneto-optical disks; and optical disks. Storage devices suitable for tangibly embodying computer program instructions and data include all forms of non-volatile memory, including by way of example semiconductor memory devices, such as EPROM, EEPROM, and flash memory devices; magnetic disks such as internal hard disks and removable disks; magneto-optical disks; and CD-ROM disks. Any of the foregoing can be supplemented by, or incorporated in, ASICs (application-specific integrated circuits).

[0045]   A number of implementations of the invention have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the invention. Accordingly, other implementations are within the scope of the following claims.